FLARE - Preliminary wire tests – Rev. A

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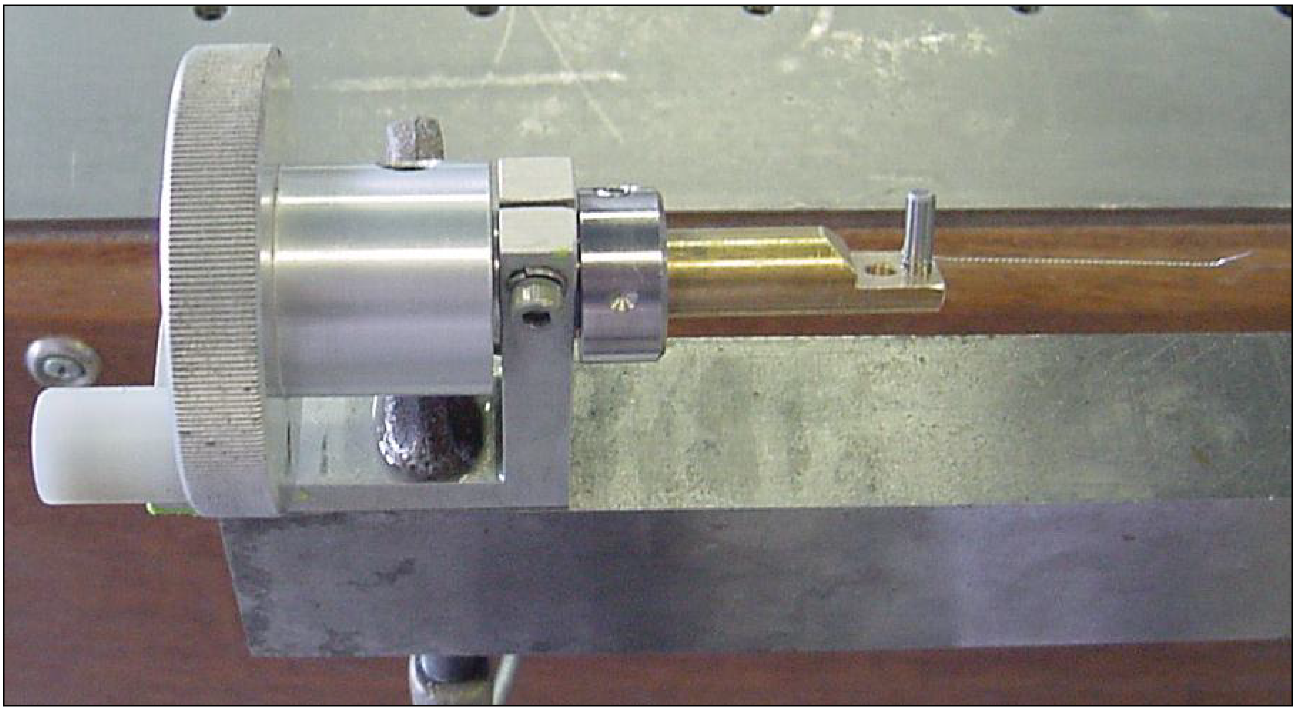
Tests

In principle, the wires in the Flare detector will be tensioned by free weights. In one end, each wire is attached to a G-10 board, which also collects the electric signals. The other end of the wire is attached to a free weight, providing the proper wire tension. The wires have to be oriented vertically at the point where the weight is attached. So, the stereo wires have to bend and be led to the weights by pins or pulleys. The vertical wires will also have similar arrangements because of space constraints for the weights.

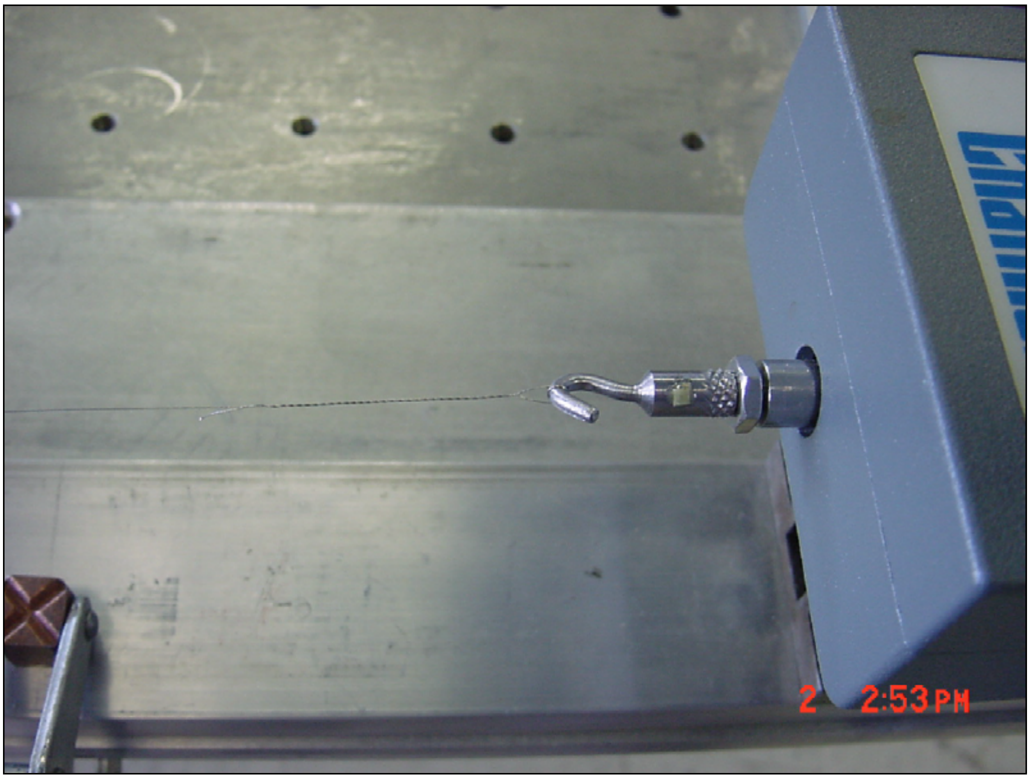
As a starting point, the connection between the wire and the weight is going to repeat what was done successfully by the 50,000 wires used on ICARUS. That is, loops are created at the ends by wrapping the wire around a pin and then around itself. Tests were made to gauge the performance of this kind of attachment. The wire was also bent around pins and pulleys and observations were made.

Setup

The wrapping of the wire was done with the help of a device built by John Korienek, as shown in the picture below. The pin has a 1/8" diameter.



The wire is wrapped around the pin manually and then the pin rotates around its base when the white plastic handle is turned. After the first end of the wire is prepared, it is then mounted to the load cell:



When the second end is ready, either the load cell or the wire wrapper can be slid to tension the wire.

A few rudimentary load cycling experiments were also performed with the help of an electric motor attached to an eccentric with a bearing mounted to it, as shown below.

To compare the effect of bending the wire around a pulley or a pin, one end of the wire was attached to the load cell and the other end was attached to weights. The wire used was identified as 5.5 mil diameter 304 stainless steel.

Observations and Results

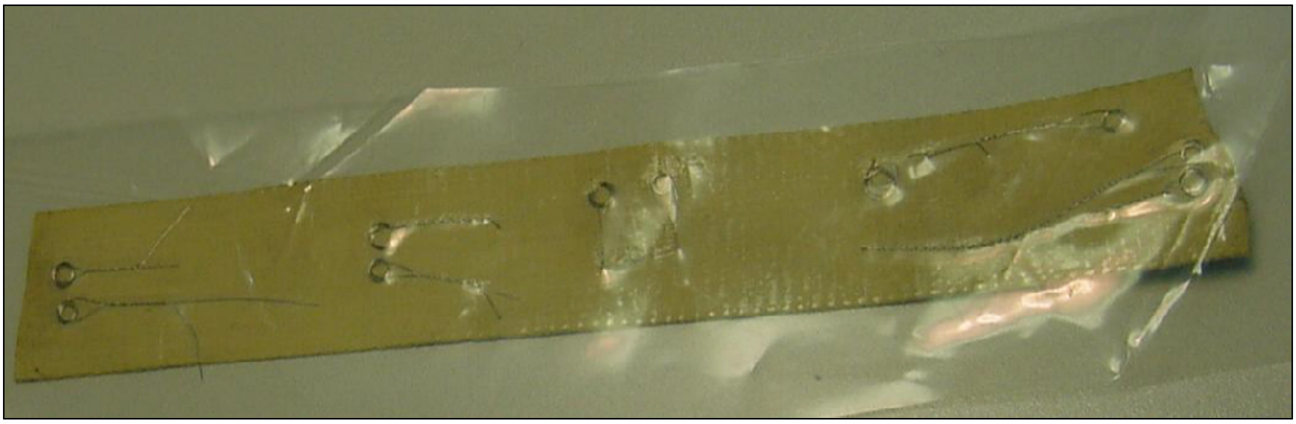
<u>Tension Tests</u>

Configurations with different numbers of wraps around the pin and different wraps around the wire were tried. At least 2 wraps around the pin and 4 wraps around the wire itself are required to prevent unwrapping. The results are listed in the table below.

loops around pin	Loops around wire	test result
1	10	unwound
1	20	unwound
2	3	unwound
2	3	unwound
2	4	Broke
2	4	Broke
2	5	Broke
3	3	unwound
3	3	Broke
4	10	Broke
4	10	Broke
4	10	Broke
4	10	Broke
4	10	Broke

The maximum load never exceeded 1.510 kg, amounting to maximum tensile stress of 140 ksi. For comparison, Sandvik 11R51 ANSI 302 stainless steel wire 0.150 mm in diameter is listed with nominal tensile strength of 367 ksi, substantially higher than the wire tested. The minimum rupture load registered was slightly below 1.4kg.

All the tests where the wire broke show the point of rupture away from the ends. It seams like the wrapping has a strengthening effect on the wire, rather then weakening. This was confirmed in 6 other tests with very short wires – see picture below.



One sample had no straight section and also had a little overlapping between wraps, and it broke at 2.2 kg. Speculating, the friction between the wrapped and straight portions of the wire (which prevents the unwinding) may transfer some load from the straight part to the coiled part, making that region behave like it is reinforced.

Cycling

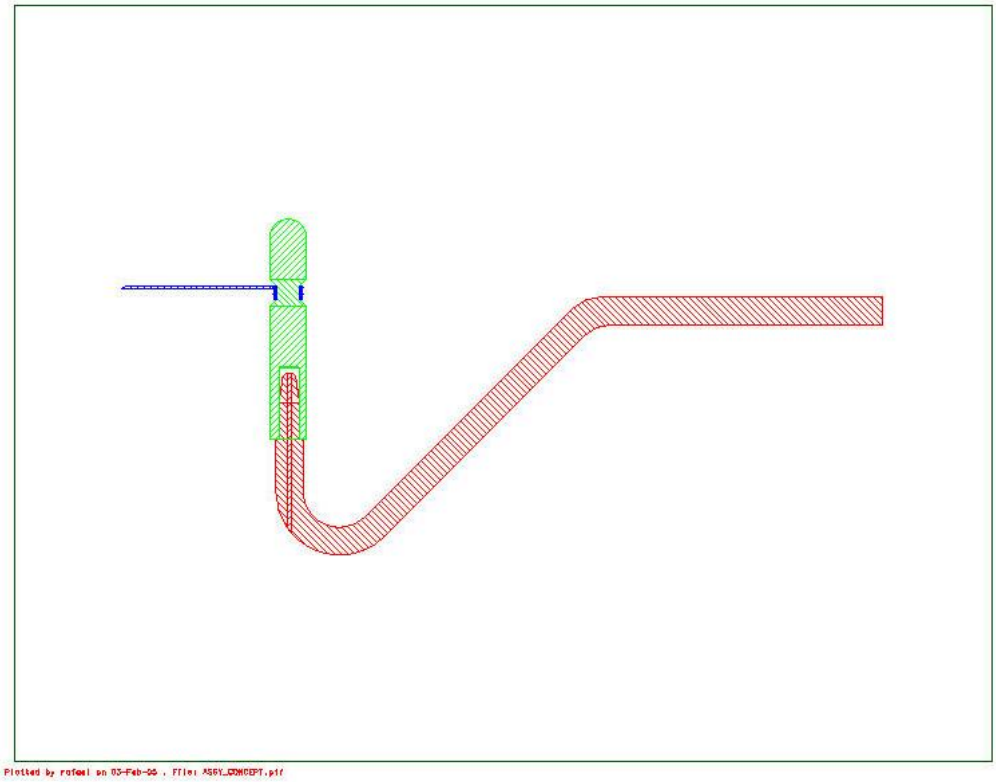
The weight at the of the wire rested on the floor at every cycle. Cycling wires with looped ends attached to screws, broke the wire at the end in a couple of cycles, likely due to the stresses generated by the contact between the wire and the crests of the thread. Replacing the screws with round pins provided a substantial improvement, however, the wire still broke after just a few cycles, perhaps not even 50.

A pair of wires crimped with aluminum at the ends were also tested. The crimp material and tool were not ideal. One wire broke at the crimped area and the other slipped, just after a couple of cycles.

Ends

I seems like, for design purposes, the wrapping technique to form the end loops is sound. Tests with the wire intended to be used in the detector and different pin diameters should be conducted. A detailed analysis should also explain the strengthening effect of the wrapping. As the wires in the detector must not break, more tests must be performed such as intentionally damaged wires, long term, low and high cycle fatigue, and tests immersed in argon.

As far as making the loops at the end of the wire, Korienek's device produces more consistent results than knots and manual wrapping. The pin holder can be improved by eliminating the material that sticks beyond the pin and rubs against the wire when wrapping. One alternative is to make the pin look like shown below.



Pulleys

With the weights hanging vertically from the load cell, the reading was 1.290kg. Mounting the load cell horizontally and running the wire through the pulley with roller bearing, the reading was 1.255kg. Mounting another pulley with a bushing bearing, the reading was a few grams lower but, after plucking the wire, the reading increased to the same 1.255kg. Fixing one end of the wire and moving the other end, which was attached to the load cell, it broke at 1.450kg.

Mounting another pulley at the other edge of the optical table, so the wire made a 90° horizontal turn around the first pulley and then a 90° vertical bend around the second pulley. The pulleys worked the same as when working separately: no effect on the reading.

Replacing the pulley with a 1/2" diameter stainless steel dowel pin, the reading decreased to 1.000 kg. Moving the cell back and forth, the load varied by +/- .250 kg. Plucking had no effect. Using a 1/4" diameter pin worsen things: reading of .890 kg and variation of about 0.300 kg. Installing a brass pipe over the 1/4" diameter pin yielded readings similar to the 1/2" diameter pin. The variation in tension without the pulley seems unacceptable. The difference in performance between the pulleys with bearings and the pipe over the rod may be due to the diameter of the pulleys and their lower friction. Pulleys seem to be the preferred method, but prototypes should be made and tested.

The sensitivity of the size of the area of contact between two cylindrical surfaces and their diameter can be inferred from the charts shown below (same chart, different scales). That may serve as an indication of one of the reasons - surface finish and material are other two - why a bushing bearing performs better than a piece of pipe sliding over a pin with a relatively large clearance.

Bearing Sensitivity to Ratio of Diameters

From R&Y, 6th ed., p.651, case 2c:

Load per unit length (lb/in): p

Assuming both cylinders of the same material - steel (psi): E

Internal cylinder diameter (in): D_2

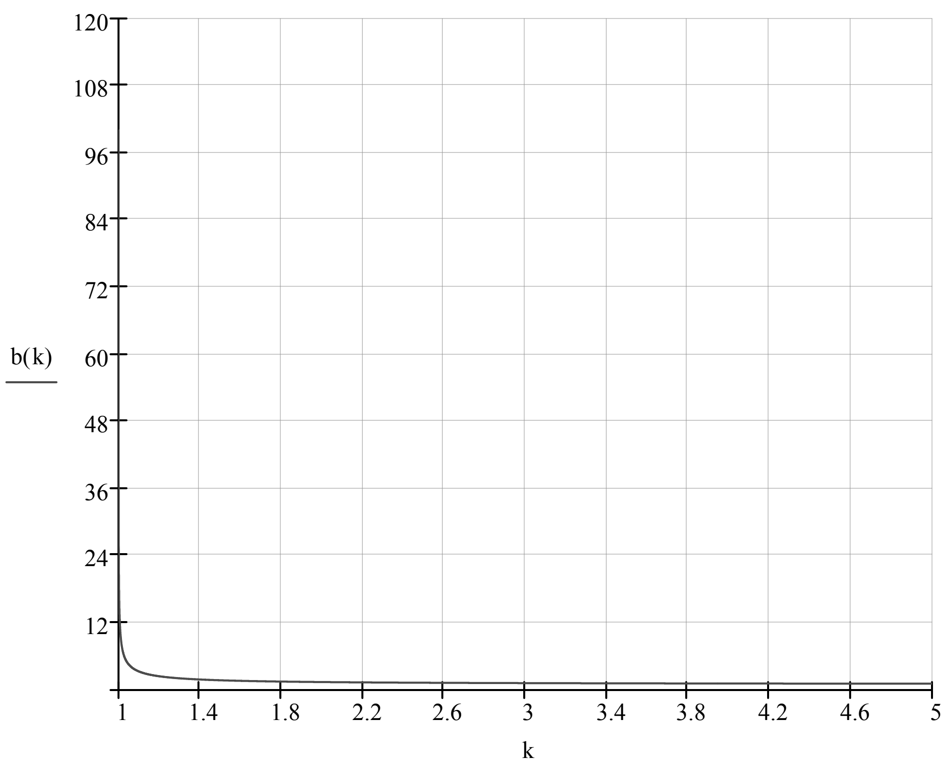
External cylinder diameter (in): D_1

D1 / D2 : $k := \frac{D_1}{D_2}$

With of rectangular contact area (in): $b := 2.15 \cdot \sqrt{\frac{p}{E} \cdot D_2 \cdot \frac{k}{(k-1)}}$

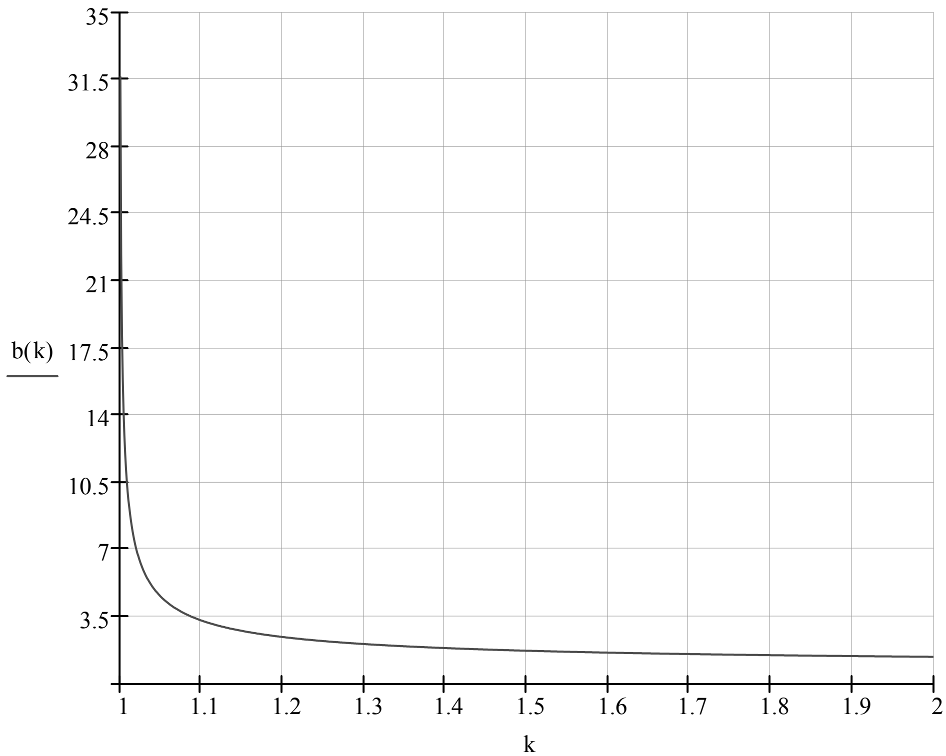
With: $c := 2.15 \cdot \sqrt{\frac{p}{E} \cdot D_2}$ Then: $b := c \cdot \sqrt{\frac{k}{(k-1)}}$

k: $k := 1.0001, 1.0002 .. 5$ $b(k) := \left[\sqrt{\frac{k}{(k-1)}}\right]$



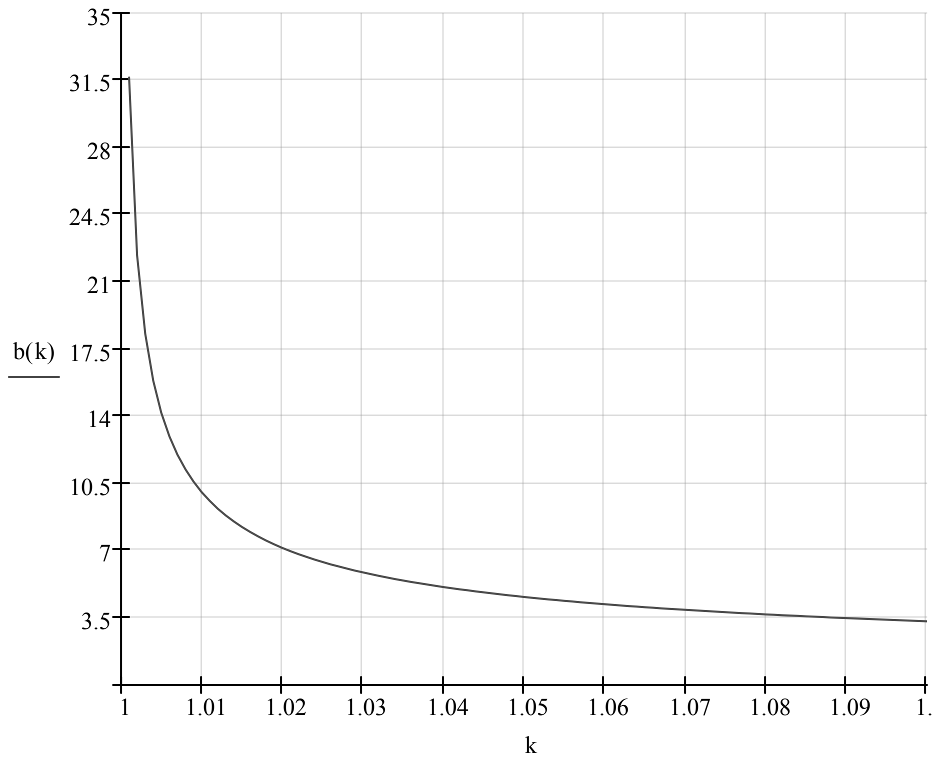
k:

$k := 1.001, 1.002 .. 2$ $\qquad$ $b(k) := \left[\sqrt{\frac{k}{(k-1)}}\right]$



k:

$k := 1.001, 1.002 .. 1.1 \qquad b(k) := \left[\sqrt{\frac{k}{(k-1)}}\right]$



$k := 1.0001 \qquad b(k) = 100.005$

$k := 1.001 \qquad b(k) = 31.639$

$k := 1.004 \qquad b(k) = 15.843$ (~clearance for 1/4" bearing)

$k := 1.01 \qquad b(k) = 10.05$

$k := 1.1 \qquad b(k) = 3.317$

$k := 1.25 \qquad b(k) = 2.236$ (internal = 1/4", external 1/16" larger)

$k := 5 \qquad b(k) = 1.118$

$k := 10 \qquad b(k) = 1.054$

$k := 100 \qquad b(k) = 1.005$